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TECHNICAL MEMORANDUM

DATE:	January 14, 2004
TO:	Water Quality/Water Resources Subcommittee; Calleguas Creek TAC
CC:	TMDL Tools Workgroup Salts TMDL Workgroup
FROM:	Mitchell Mysliwiec Armand Ruby
SUBJECT:	Salts Conceptual Model for the Calleguas Creek Watershed

DRAFT

CONCEPTUAL MODEL

Overview

Salts management in the Calleguas Creek Watershed (CCW) is a complicated issue. Drinking water is imported to the watershed to sustain the water supply demands of the local population and agricultural users. Precipitation adds water to the system but carries little salt load. Soils in the watershed are derived from historic marine sedimentation, which trapped minerals during their formation. These minerals may be dissolved to contribute to the groundwater salt load. The surface water creeks are highly connected to the shallow groundwater aquifers. Irrigation represents a substantial water use, and evapotranspiration acts to concentrate and strand salts in the top layers of soil. The only mechanism removing salts from the watershed is the network of creeks and agricultural drains carrying their load of salts as the water flows through Mugu Lagoon to the Pacific Ocean. Water use and the distribution of uses across the watershed affect the salt budget in an intricate manner.

Significant loads of salts are added to the surface waters by groundwater exfiltration (baseflow) and other non-point sources upstream from the wastewater treatment plants, so exclusively controlling treatment plant effluents will be unlikely to bring all surface water quality to within the Basin Plan objectives. The groundwater exfiltration is relatively high in salts concentrations due to dissolution of the historic marine sediments and flushing of stranded salts. Because a large fraction of the water supply originates from the relatively low-salt-concentration State Water Project, discharges from the publicly owned treatment works (POTWs) are typically within Basin Plan objectives.

A conceptual model serves as a tool for data synthesis, communication and education, and planning. The past and present conditions of a pollutant in the watershed, including the relevant physical, chemical, and biological processes, are all embodied in the conceptual model. Stakeholder involvement in the development of the conceptual model inspires communication and education of the members. Once a satisfactory level of agreement is achieved for the conceptual model, additional modeling may proceed to facilitate informed planning decisions regarding management of salts in the watershed.

Watershed Description

The Calleguas Creek Watershed encompasses an area of 343 square miles. Development within the watershed over the past half century now supports an urban population of over 400,000 people, primarily in the upper reaches of the creeks and arroyos, and 50,000 acres of irrigated agriculture in the lower watershed. Urban water needs are met principally through the importation of water from the State Water Project, with some contribution from the Freeman Diversion, on the Santa Clara River, and groundwater wells. Agricultural water demands have historically been satisfied by mining deep groundwater from the Fox Canyon Groundwater Aquifer System and importing surface water from the neighboring Santa Clara River Watershed via the Freeman Diversion. A depiction of the watershed features is presented in Figure 1.

The watershed is semi-arid, receiving an average of 15 inches of rainfall per year (at Moorpark) with a historical annual range of 6 inches to over 30 inches. Nearly all of the rainfall occurs between November and March. The watershed has relatively few surface water features. There are no natural lakes and no major rivers. The surface waters are primarily arroyos and creeks that have historically carried storm flows and post-storm flows from the upper watershed down to the alluvial valleys and the southeastern portion of the Oxnard Plain. Prior to the effects of large-scale water management projects, these streams were ephemeral and only occasionally flowed from the upper watershed to the ocean (Hajas, 2003).

Figure 2 is a simplified schematic of water use and salts loading to the watershed. When considering salt and water flows, the entire watershed may be broken into an upper watershed including the Arroyo Simi and Arroyo Las Posas, and the lower watershed which includes the Arroyo Santa Rosa, Revolon Slough, and Conejo and Calleguas Creeks. Generally, each of the water sources depicted in Figure 2 include two subscripts; the first identifying the location of the source, and the second identifying the source as a surface water (S), groundwater (G), or blend (S/G). Precipitation on the watershed is represented in Figure 2 by a long, dashed arrow to indicate the event-based nature of rain. Upper Calleguas Creek is the surface water body connecting the upper and lower watersheds. Because of the geologic conditions underlying the Arroyo Los Posas in the area around Moorpark, the entire creek flow infiltrates into the groundwater at all times except during high-flow runoff events, leaving the Upper Calleguas Creek dry under all but heavy precipitation conditions. Some groundwater transfer may occur between the upper and lower watersheds. Transfer by surface and groundwater between the upper and lower watersheds is shown in Figure 2 by a dotted arrow ($Q_{Transfer}$) to indicate the sporadic surface water flows and largely unquantified groundwater flow. Groundwater used for irrigation and limited municipal blending is a minor source of water. Imported surface water is the dominate source of water to the watershed. Because there are no natural perennial surface water bodies in the watershed, on most days the flows in each of the surface water sources depicted in Figure 2 derive from an imported water source. Note that the only export mechanism for salts is the flow to the Pacific Ocean through the Mugu Lagoon, shown as Q_{Ocean} in Figure 2.

Upper Watershed

The upper watershed includes Simi and Las Posas Valleys. The main surface water bodies are the Arroyo Simi, Arroyo Las Posas and the uppermost reach of the Calleguas Creek. The groundwater bodies include the Las Posas Basin, one of the major aquifers within the Fox Canyon Aquifer System, and the South Las Posas Basin and the Simi Valley Basin, both unconfined groundwater basins. Development on the northern reach includes the City of Simi Valley, the City of Moorpark, and some 19,000 acres of irrigated agriculture, shown as Q_{SV}, Q_{MP}, and Q_{AG}, respectively in Figure 2. The northern reach has two POTWs: the Simi Valley Water Quality Control Plant and the Ventura County Waterworks District # 1 plant (Hajas, 2003).

Lower Watershed

The lower watershed is comprised of Conejo, Tierra Rejada, Santa Rosa and Pleasant Valleys. The surface water bodies are Conejo Creek and its tributaries, the lower reach of Calleguas Creek and Revolon Slough, a constructed agricultural drain. The major developments of the southern reach are 38,500 acres of irrigated agriculture, the City of Thousand Oaks, the City of Camarillo, and the California State University, Channel Islands (CSUCI), shown as Q_{AG}, Q_{TO}, Q_{Cam}, Q_{CSUCI}, respectively in Figure 2. The southern reach has three POTWs: the Hill Canyon Wastewater Treatment plant, serving Thousand Oaks; the Camarillo Sanitary District plant, serving western and southern Camarillo; and the Camrosa Wastewater Reclamation plant, serving eastern Camarillo and CSUCI (Hajas, 2003). Calleguas Creek flows to the Pacific Ocean via Mugu Lagoon and is represented by Q_{Ocean} in Figure 2.

Groundwater

Groundwater features of the watershed are dominated by the Fox Canyon Aquifer System, which is linked to the neighboring Santa Clara River Watershed. The Fox Canyon Aquifer System is a series of deep, confined aquifers that were filled ages ago. These aquifers today receive little or no recharge from the CCW. The water quality in these aquifers is very high. However, because there is little recharge to these aquifers they suffer from overdraft. The two major aquifers within the CCW are the Las Posas Basin and the Pleasant Valley Basin (Hajas, 2003).

Shallower, unconfined groundwater basins are located in the valleys of the watershed. In the upper sub-watersheds of Simi Valley and Conejo Valley, groundwater collects in the lower areas and overflows into the down-gradient valleys. The Tierra Rejada, Santa Rosa and South Las Posas valley basins are larger than the upper valley basins and are the most significant unconfined basins on the watershed. Areas of perched and unconfined groundwater are also present along the base of the Santa Monica Mountains, and overlying areas of the southeastern

Oxnard Plain in the Pleasant Valley. In the early years of land development in the watershed these groundwater basins were quickly overdrafted (Hajas, 2003).

Eastern and Southern Las Posas Basin groundwater is used as a source for both agriculture and municipal supply (Bachman, 2002). Over the past two decades, chloride and TDS concentrations have risen along with the groundwater surface elevations in the basin. Possibly the downward-percolating, high-salts-concentration agricultural return flows have been intercepted by the rising groundwater, resulting in the increased salts concentrations.

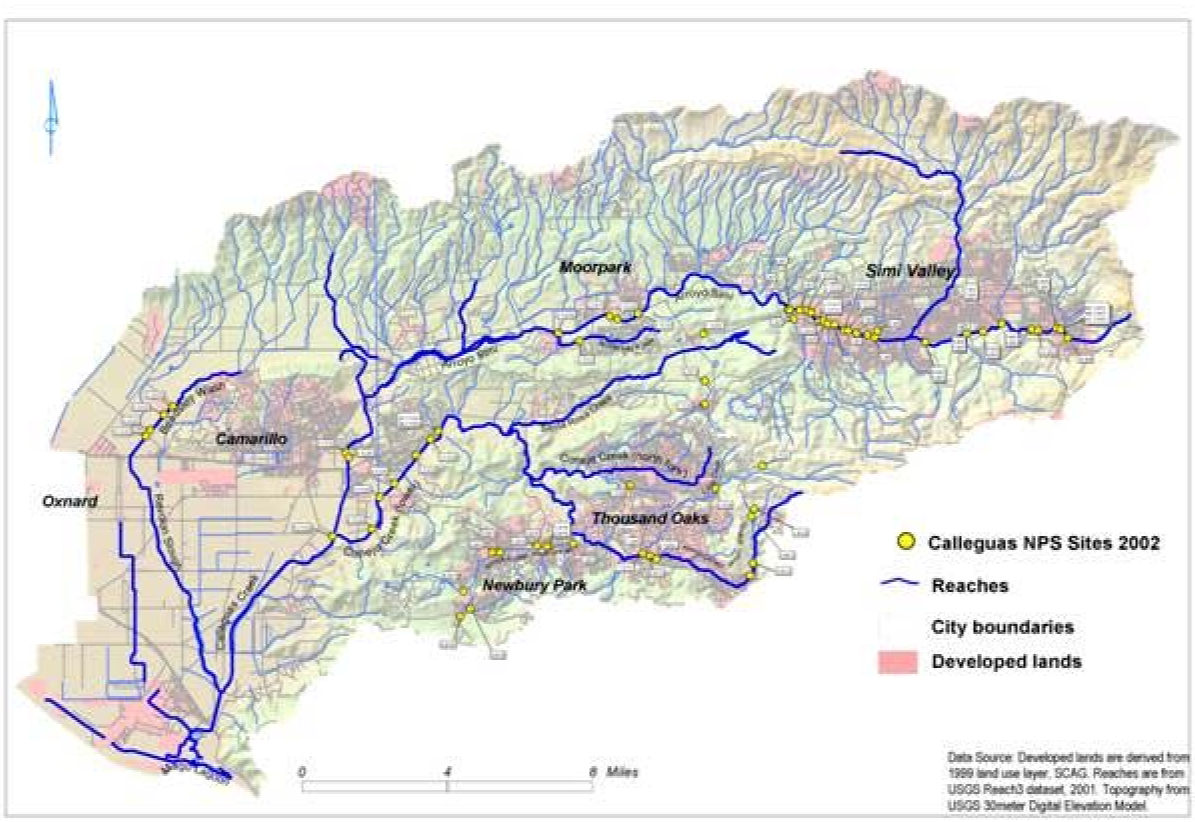

Figure 1: Calleguas Creek Watershed site map.

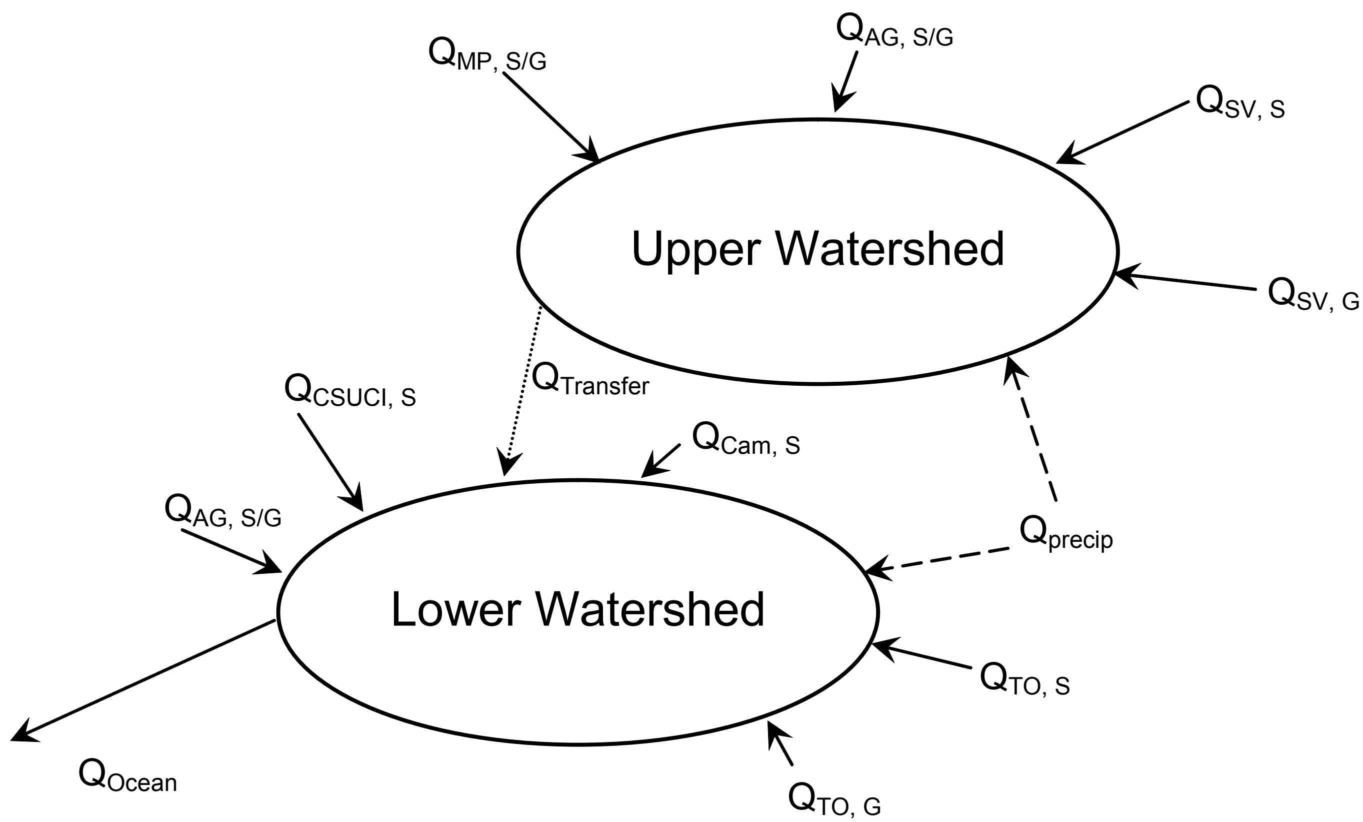

Figure 2: Overall schematic of salts flows through the Calleguas Creek Watershed. Water flow introduced to the watershed are indicated with a Q with subscripts identifying the generalized locational source of water along with whether the source is a surface water (S), groundwater (G), or blend (S/G).

Sources of Salts

Salts are primarily added to the watershed through the imported water supply (including principally the State Water Project, but also deep aquifer groundwater sources). Human use of water concentrates and adds salts to the water. Some activities, such as the use of water softeners, contribute significant amounts of chloride to sanitary sewers. Septic tanks are a potential source of salts to the groundwater; however nearly the entire population is serviced by sanitary sewers. Irrigation concentrates salts through evaporation and evapotranspiration, but agricultural activities generally do not otherwise add salts to the discharged water. Additional salts may be contributed to groundwater or surface waters as rainfall or irrigation water leaches salts from soils derived from marine sediments.

Sources of salts to the Calleguas Creek Watershed may be generally categorized as external and internal. External sources are the salts load carried in the imported water supply and precipitation. Examples of internal sources are the increase due to typical human use, water softener regeneration, chemical disinfection of drinking water, and wastewater treatment plant effluents. Salts are removed from the watershed by transport to the Pacific Ocean through Mugu Lagoon via the network of creeks. Once completed, the planned brine line also can be used to remove salts from the watershed. Brief descriptions of the various processes included in the conceptual model are as follows:

External Water Sources and Sinks

Imported Water: Drinking water imported to the watershed including State Project Water and Freeman Diversion water. A major source of salts to the watershed is the load associated with imported water sources. While the concentration of salts in the imported water is low relative to Basin Plan Objectives, the quantity of water brought into the watershed is sufficient to rate imported water as the number one source of salts to the watershed.

Groundwater Pumping: Groundwater pumping occurs in the watershed to dewater high groundwater tables, as irrigation supply, and as augmentation to imported municipal water supplies. High groundwater levels in the Simi Valley require dewatering to prevent seepage into developed areas. Dewatering flows are typically discharged to the Arroyo Simi via local creeks.

Groundwater Infiltration/Exfiltration: Soils in the watershed are derived from marine sediments. Over geologic time and before watershed development occurred, groundwater leached salts from the soil, allowing salts concentrations to equilibrate between the surface water and groundwater. Increases in groundwater levels due to development may cause saturation of soil previously above the water table, allowing salts to dissolve into the groundwater, increasing concentrations and liberating salts for transport to the surface water.

Precipitation: Precipitation is not thought to be a significant source of salts to the watershed. Precipitation acts to flush accumulated salts from the system carrying them to the ocean via the natural watershed drainage.

Diversions: Water diverted from the creek, principally for irrigation uses. TMDL implementation alternatives under consideration include additional diversions.

Internal Water Use and Modification

Users: Includes domestic use of water for drinking, and irrigation use. The routine human use of water acts to add salts to water discharged to the sewer. Studies performed in the adjacent Santa Clara Watershed yielded an average chloride increase of approximately 30 mg/L from water supply to discharge to the sanitary sewer.

Water Softeners: Waste discharged from self-regenerating water softeners is a source of salts to the sanitary sewer system.

POTWs: POTWs may add salts during treatment. Chemical disinfection typically employs chlorine or chlorine-containing compounds as an active ingredient. As part of the disinfection process, chlorine breaks down to chloride.

Irrigation Runoff: Runoff from urban landscape and agricultural crop irrigation. Evapotranspiration will act to concentrate the salts in groundwater and soils. Over-irrigation may transport previously stranded salts.

Evapotranspiration: Evapotranspiration of irrigated water does not affect the mass of salts present, but does remove water from the watershed, concentrating salts in the remaining water. Evaporation of water from the surface waters has an identical effect on salts concentrations. As water evapotranspires the salts are concentrated, potentially becoming stranded out of solution in crustal deposits.

Precipitation Runoff: Runoff from urban, agricultural, and open space lands. Runoff quality is likely to be different from each land type. The runoff may transport previously stranded salts to the surface waters.

Hydrodynamics: Surface waters carry a load of salt, moving the salts down the watershed. In fact, the only process currently removing salts from the watershed is the flow of Calleguas Creek to the Pacific Ocean through Mugu Lagoon. Flow processes in the watershed are complex; in the headwater areas of the major creeks groundwater exfiltration provides the majority of the flow. In certain areas of the watershed, groundwater recharge is a significant sink of water. The surface waters and shallow groundwater are tightly coupled.

Conceptual Model

A conceptual model of salts sources and transport is presented diagrammatically in Figure 3. This diagram is meant to provide a generalized conceptual overview of the salts sources and related processes occurring throughout the watershed. Figure 3 is not spatially specific, in that some of the sources and processes may predominate in certain areas of the watershed and be absent from other areas. The internal and external variables discussed above are represented in Figure 3 with different polygons. Development of a numerical, predictive model of the salts flow through the watershed is guided by the conceptual model. Review of available data allows refinement of the conceptual model, and helps inform development of the predictive model. Data are evaluated to determine if processes included in the conceptual model can be supported in the predictive model. The developed numerical model should be able to account for all processes in the conceptual model that are supported by data.

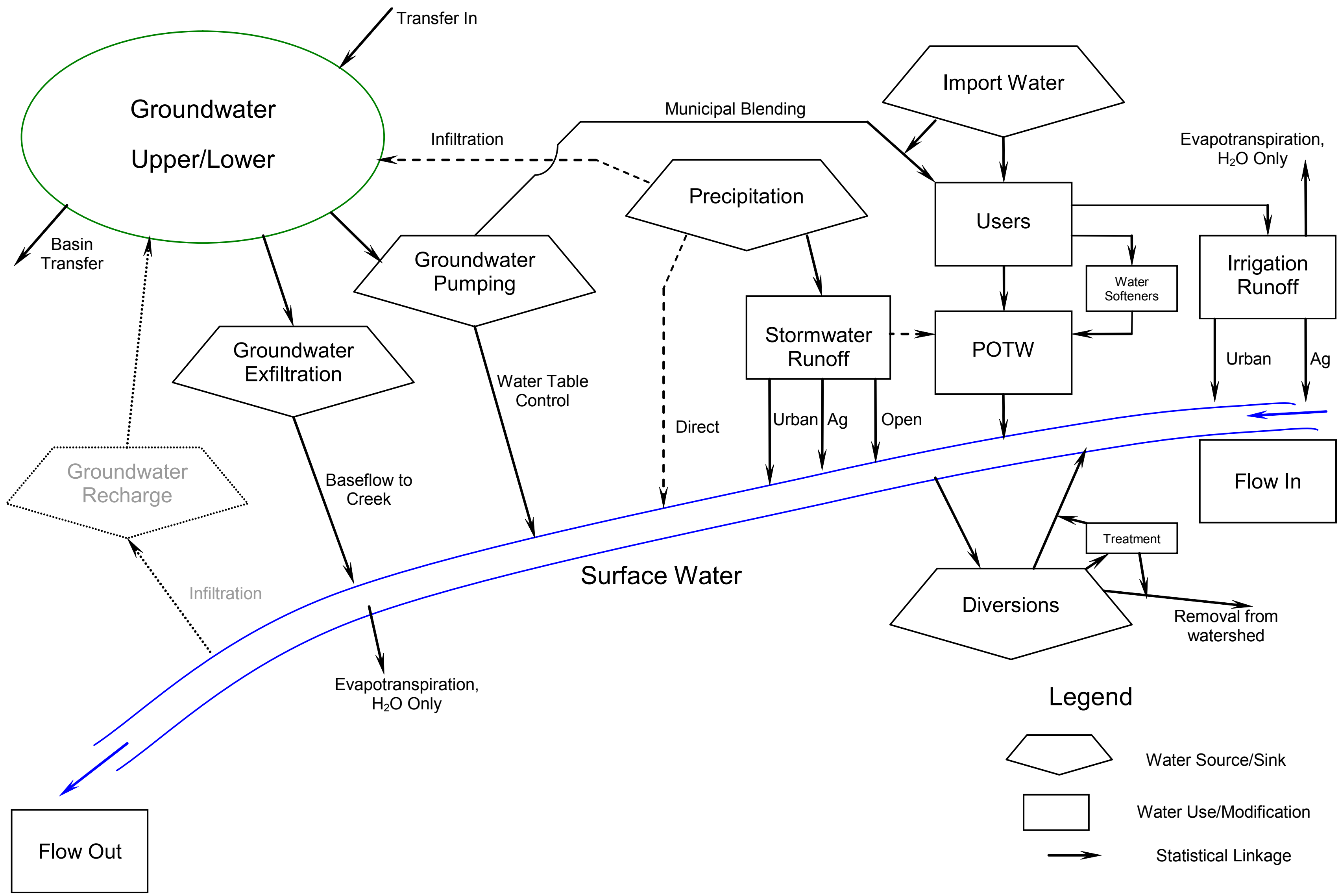

Figure 3: A Generalized Conceptual Model of salts flow for the Calleguas Creek Watershed.

Communication

The conceptual model is used as a tool to communicate with the stakeholders as to how the system is thought to operate. By design, the conceptual model is a flexible and fluid document. Revisions to the conceptual model are expected to occur as agreement is built among stakeholders as to the important processes, available data, and sources and sinks of salts.

Planning

The conceptual model serves as decision support for planning activities. As stakeholder agreement is built for the importance of various watershed processes in contributing to salts movement into and through the watershed, a forum for ranking projects and alternatives to manipulate salts in the watershed could be created during the conceptual model process.

Uncertainty Assessment

The conceptual model is used to highlight uncertainties in:

- Indicators of impairment
- Source Assessment
- Linkages connecting sources to impairment
- Surface water recovery time

Recognition of the magnitudes of uncertainties for each component represented in the conceptual model highlight existing data gaps; pointing toward areas where additional effort may be beneficial.

Projects to Reduce Uncertainty

Increased information about the watershed will most likely reduce uncertainty in model estimations. Because the probability distributions used in the stochastic components of the modeling are estimated from the available data, increasing the amount of data and reevaluating the distributions will likely reduce uncertainty in the model output. As data are collected and new information becomes available, the conceptual model should be reevaluated and updated as appropriate.

Proposed Actions

Implementation activities currently under consideration include:

- Construction of a brine line in the upper watershed.
- Conejo Creek diversion project.

Both projects are in planning. The operation of each of the projects will be guided by the results from the modeling effort.

Project Prioritization

Projects currently under consideration for the watershed include water management procedures to reduce the potential for salts to build-up and means for aiding salts flow to the ocean. As projects and alternatives are developed, they may be prioritized by how well uncertainties are addressed and by which mechanisms in the Conceptual Model are manipulated.

References

Bachman, S. (2002), Water Quality in the East and South Las Posas Basin: Problems and Solutions", for Calleguas Municipal Water District, July 2002.

Hajas, R. (2003), "Salt Loading on the Calleguas Creek Watershed", Memo to Calleguas Creek Watershed Water Quality / Water Resources Sub-committee, Dated December 10, 2003.